

COVER SHEET

U.S. PATENT APPLICATION
(DEPENDENT FOR PRIORITY ON U.S. PROVISIONAL
APPLICATION NO. 60/392,369)

ENTITLED:
EXCAVATOR TEETH, APPARATUS AND METHODS

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1 **EXCAVATOR TEETH, APPARATUS AND METHODS**

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3 **RELATED APPLICATION DATA**

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5 This application depends for priority on U.S. Provisional Patent
6 Application No. 60/392,369, filed July 1, 2002.

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8 **TECHNICAL FIELD**

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10 The invention relates to teeth useful in connection with excavating
11 machines, and to digging implements and excavating machines
12 comprising such teeth.

13
14 **BACKGROUND**

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16 The teeth commonly employed on digging implements for excavation
17 machines, such as for bucket leading-edges, ripping arms and dredge-
18 heads, have a limited service life, depending in part upon the severity of
19 the abrasion to which they are subjected. Severe applications include
20 rock fracturing and removal, and excavation of frozen earth. In a rock
21 trenching operation in Ohio, U.S.A. sandstone with a very powerful
22 excavating machine having a digging implement equipped with cast high
23 abrasion resistance alloy teeth, service lives as low as less than an hour
24 were experienced. This invention seeks to fulfill a need for improved
25 excavator teeth and excavation methods.

26
27 **SUMMARY OF THE INVENTION**

28
29 In one aspect, the invention relates to an excavator tooth useful
30 for fracturing rock strata. It comprises a metallic core having front
31 and rear ends and at least one longitudinal surface extending between
32 said ends. There is also at least one projection formed from metallic
33 stock, which may for example be bar stock of round, square or
34 rectangular cross-section, or more preferably may be plate stock.
35 A projection according to the invention has a tip, which is an end of
36 the projection, of whatever shape, that is intended to act on the rock or
37 other material on which the tooth may be used. Such projection
38 is secured to the core, at least in part by welding, with the tip and at
39 least portions of the length of the projection(s) extending beyond the
40 front end of the core. In or on the core there is at least one tooth
41 connector portion, including at least one concave or convex connector
42 surface, of circular or other configuration, positioned and adapted to

1 engage with and non-destructively disengage from at least one mating
2 surface of an excavator apparatus.

3 The invention has a variety of additional aspects, among which are
4 preferred and highly preferred embodiments. For example, the core may
5 be of circular or non-circular cross-section, and may have a single
6 longitudinal surface in the form of a cylinder or plural longitudinal surfaces.

7 The at least one projection preferably includes at least one cut edge, an
8 edge formed at least in part in cutting the projection from the metallic stock,
9 and this edge may for example be an end of the projection when it is cut to
10 length from bar stock. More preferably, the cut edge is a longitudinal edge,
11 for example an edge resulting from cutting the projection from a plate.

12 It is preferred that the projection metallic stock thickness be about 1/2 to
13 about 3, or about 3/4 to about 2 and 1/4 or about 1 to about 1 and 1/2,
14 inches. This dimension will correspond, for example, to the diameter of
15 round bar stock or the thickness of plate stock.

16 In a particularly preferred embodiment, the tooth includes at least one
17 projection which has on opposite sides thereof, as viewed in transverse
18 cross-section, at least two approximately planar surfaces which are
19 approximately parallel to one another. Preferably, these surfaces of the
20 projections are approximately parallel to the digging direction of the tooth.
21 More preferably, when viewed in transverse cross-section and when
22 positioned vertically in the view, these surfaces are at least about as tall as
23 the distance between them.

24 Preferably, there are at least two projections on the excavator tooth. More
25 preferably, these are secured to substantially opposite sides of the core.

26 In a particularly preferred embodiment, there are at least two projections
27 that have inner surfaces, portions of which surfaces generally face one
28 another and extend forwardly from the core. These portions, as they
29 progress toward their tips, have an angle of divergence between them of
30 about 0 (i.e., no divergence or a small convergence) to about 30 degrees,

1 preferably about 2 to about 30 degrees, more preferably about 12 to about
2 24 degrees, still more preferably about 16 to about 20 degrees and most
3 preferably about 18 degrees.

4 In another aspect, the projection metallic stock is preferably of abrasion
5 resistant steel having a surface BHN (Brinell Hardness Number) of at least
6 about 225, more preferably at least about 300, more preferably at least
7 about 350, more preferably at least about 375 and more preferably at least
8 about 400, at least prior to its fabrication into teeth according to the
9 invention, and more preferably after such fabrication.

10 Preferred embodiments of the projection metallic stock comprise iron,
11 carbon, manganese and silicon, and optionally but preferably at least one
12 additional alloying element selected from the group consisting of chromium,
13 nickel, boron, molybdenum, vanadium, titanium, copper, aluminum, niobium
14 and nitrogen. More preferably, the sulfur and phosphorous contents of the
15 metallic stock are respectively less than about 0.05, preferably less than
16 about 0.04 and still more preferably less than about 0.030 percent by
17 weight of the entire stock.

18 In a preferred embodiment, there is a narrowing of at least one projection,
19 between its generally longitudinal edges, in the direction of the tip, which
20 may for example occur along a single edge.

21 However, in still more preferred embodiments, first and second longitudinal
22 edges of at least one projection, or more preferably first and second edges
23 of a plurality of projections, converge with one another, along at least a
24 portion of their respective lengths, in the direction of their tip or tips.

25 In a particularly preferred embodiment, such narrowing, or such
26 convergence, exists at least closely adjacent to the tip or tips.

27 Most preferably, the projection edges converge, as the edges approach the
28 tips, preferably at an angle of about 10 to about 35 degrees, more
29 preferably about 15 to about 30 degrees, still more preferably about 17 to
30 about 25 degrees and even more preferably about 21±2 degrees.

1 A particularly preferred form of the invention comprises convergence of at
2 least portions of projection longitudinal edges along substantially straight
3 lines, preferably closely adjacent to their tip or tips.

4 Preferably, convergence occurs over at least about 25% and more
5 preferably up to at least about 100% of the length of the projection
6 longitudinal edges

7 Preferably, the projection or projections respectively include two convergent
8 edges that are cut edges.

9 It is preferred that at least one projection be secured to the core through at
10 least one longitudinal surface of the core. Advantageously, the projection
11 or projections is/are secured to the core preferably entirely, by welds. In a
12 particularly preferred embodiment, said at least one longitudinal surface
13 has a plurality of projections secured thereto at least in part by welds
14 between the at least one surface and adjacent portions of the projections.

15 The tooth connector portion may be located at the rear end of the core,
16 preferably in or on a rearmost surface of the core.

17 Wherever located on the core, the tooth connector portion may be securely
18 connected with a mating surface of an excavator apparatus. In a preferred
19 embodiment, the tooth connector portion is a female member extending
20 into the rear end of the core and the mating surface is a male member on
21 an excavator apparatus, or vice versa.

22 A locking member may be present, e.g., a resilient insert or metallic pin, to
23 engage the tooth and a portion of the excavator apparatus, thus providing
24 security for the connection between the tooth connector portion and the
25 mating surface.

26 According to the invention, the excavator apparatus may be any excavating
27 machine adapted to carry, in working position, one or more teeth
28 constructed according to the invention. Such excavator apparatus may for
29 example be an excavating machine selected from the group consisting of

1 power shovels, backhoes, draglines, dredges, graders and bulldozers, or
2 may be a digging attachment or combination of attachments adapted to be
3 mounted on an excavating machine and to carry, in working position, one
4 or more of said teeth.

5 In one particular embodiment, the excavator tooth is connected with a
6 bucket having a mounting pin for connecting the bucket to an excavating
7 machine. The tooth has a projection with a major surface which is held in
8 approximately perpendicular relationship with the longitudinal axis of the
9 mounting pin.

10 Another embodiment includes an excavator tooth connected with a rock
11 ripping tool having a mounting pin for connecting the tool to an excavating
12 machine. Here, the tooth has a projection with a major surface which is
13 held in approximately perpendicular relationship with the longitudinal axis of
14 the mounting pin.

15 Still another embodiment comprises an excavator tooth connected with a
16 bucket or blade at a substantially rectilinear cutting edge of the bucket or
17 blade. That edge is or has a digging axis, and a major surface of the tooth
18 is held in approximately perpendicular relationship with that axis. On the
19 other hand, the bucket or blade may have an at least partly non-rectilinear
20 cutting edge having ends at sides of the bucket or blade. In which case, an
21 imaginary line connecting those ends defines the axis.

22 In yet another embodiment, an excavator tooth is connected with digging
23 end of a pivotable ripping arm for an excavating machine. This arm has a
24 pivoting axis about which the arm swings in operation. A major surface of
25 the tooth is held in approximately perpendicular relationship with the axis.

26 Other aspects of the invention includes methods of excavation. Among
27 these are a method of excavation with an excavating machine having an
28 arm with a pivot affording angular movement of an end of the arm about a
29 central axis of the pivot, said arm supporting and delivering digging force
30 and motion to a digging implement having projections. This method
31 comprises applying such force through projections that are formed of cut

1 plate stock and have major surfaces that are approximately perpendicular
2 to said axis.

3 The invention also includes a method of fracturing rock or frozen earth with
4 an excavating machine having an arm with a pivot affording angular
5 movement of an end of the arm about a central axis of the pivot, said arm
6 supporting and delivering digging force and motion to a digging implement
7 able to apply sufficient force through the tips of projections on said
8 implement to break up the strata. This method comprises applying such
9 force through projections that are formed of cut plate stock and have major
10 surfaces that are approximately perpendicular to said axis.

11 Optional but preferred embodiments of each of the foregoing methods
12 include applying such force through teeth having edges that converge at
13 angles as above described, and/or applying such force through teeth
14 respectively having two projections with inner major surfaces generally
15 facing one another and having an angle of divergence between them as
16 above described. Still other optional but preferred embodiments of each of
17 the foregoing methods comprise applying such force through teeth wherein
18 the plate stock is abrasion resistant steel plate having a surface BHN as
19 above described and/or having a composition as above described.

20 Other embodiments of the invention are described below, and additional
21 embodiments of the present invention, not disclosed herein, can be
22 constructed by persons skilled in the art without departing from the spirit of
23 the invention.

24 ADVANTAGES

25 This invention makes available improvements in excavator teeth. Most
26 embodiments of the invention will include one or more of the following
27 advantages. Certain preferred embodiments will include all of these
28 advantages. As compared to common, cast, replaceable steel teeth used
29 in the past, it is possible for persons skilled in the art of steel fabrication to
30 fabricate excavator teeth according to the invention which exhibit excellent
31 cutting properties, long life in rock excavation and other applications,

1 reduced cost for teeth per hour of operation and ease of fabrication. One
2 can fabricate embodiments that afford a strategic balance between service
3 life and ease of penetration of rocky strata. Moreover, the invention offers
4 the possibility of providing a range of satisfactory products which offer a
5 degree of flexibility with respect to this balance. Where the projections
6 have approximately parallel sides, then, for a given cutting edge width, the
7 invention provides improved bending resistance in the projections, as
8 compared with teeth having projections formed from round bar stock. The
9 methods of the invention offer the operational advantages set forth above.
10 Other advantages of these excavator teeth and methods will become
11 apparent to those skilled in the art upon using the invention.

12 **BRIEF DESCRIPTION OF THE DRAWINGS**

13 Figure 1 is a side view of an excavator tooth according to the invention.

14 Figure 2 is a top view of the excavator tooth of figure 1.

15 Figure 3 is a view, in perspective, of another embodiment of the invention
16 having a core which is the remnant of a cast excavator tooth from which the
17 original teeth have been worn away.

18 Figure 4 is a side view, partially in section, of yet another embodiment of
19 the invention having two projections, a portion of a projection in the
20 foreground being broken out to reveal a projection in the background and
21 parts between them.

22 Figure 5 is a perspective view of still another embodiment of the invention.

23 Figure 6 is a side view, partially in section, of the embodiment of figure 5,
24 but with the addition, in phantom outline, of a portion of an excavator
25 apparatus.

26 Figure 7 is a perspective view of a digging implement, i.e., a ripping arm,
27 having mounted on its end an excavator tooth as a shown in figures 1 and
28 2.

1 Figure 8 is a perspective view of a digging implement having thereon a
2 ripping arm and excavator tooth as shown in figure 7.
3 Figure 9 is a perspective view of a digging implement having thereon two
4 ripping arms, respectively having excavator teeth as shown in figure 7.
5 Figure 10 is an end view, with portions broken out, of a dredge cutter-head.

6 Figure 11 is a perspective view of a digging implement, i.e., a bucket,
7 having a rectilinear front edge provided with a row of excavator teeth
8 according to the invention.
9 Figure 12 is a perspective view of a digging implement, i.e., a bucket,
10 having a non-rectilinear front edge provided with adapters and with
11 excavator teeth according to the invention, two of five teeth being left off of
12 their adapters to simplify the view.

13 Figure 13 is a side view of a backhoe unit including a ripping arm equipped
14 with one or more excavator teeth according to the invention.

15 Figure 14 is a side view of a power shovel including a ripping arm equipped
16 with at least one excavator tooth according to the invention.

17 Figure 15 is a side view of a dragline unit including a bucket having
18 excavator teeth according to the invention.

19 Figure 16 is an enlarged portion of figure 15 providing greater detail with
20 respect to the bucket.

21 VARIOUS AND PREFERRED EMBODIMENTS

22 Cores may be formed of any suitable metal. Preferably, the metal of the
23 core should be readily weldable, economical and of adequate durability, for
24 example, crack resistant, ductile, reasonably hard, strong and tough. In
25 general, such metal will be chosen from among one or more alloys
26 including one or more alloying elements to promote one or more of the
27 properties of wear resistance and fracture resistance, more preferably

1 alloys that contain iron as a major component (more than 50%) by weight.
2 The cores may have and preferably do have less wear resistance than the
3 projection(s). Wear resistance should be sufficient to maintain, in rock
4 excavating service, the structural integrity required to securely support the
5 excavating projection(s) and perform their connecting function over the
6 useful life of the projection(s).

7 Fracture resistance should be sufficient to resist breakage of the core under
8 the loads imposed in rock excavating service. Rock excavating service
9 includes, for example, one or to more of the following: use on buckets or
10 other digging implements attached to the arms of backhoes engaged in
11 digging rocky soil or gravel; more preferably, use on drag-line buckets
12 engaged in the stripping of frozen earth and/or rocky overburden; and, most
13 preferably, service on buckets or other digging implements attached to the
14 arms of large and very powerful hydraulic shovels, for example, Caterpillar
15 model 385, engaged in the fracturing and subsequent removal, e.g.,
16 digging, of rock strata. The fracture resistance requirement depends on
17 loads which are sustained in operation, which to some degree depend on
18 force exerted by excavating machine, the hardness of the rock to be
19 penetrated by the tooth and leverage imposed on the core by the design of
20 the tooth, for example leverage imposed by the lengths of the core and the
21 projection(s).

22 Temper resistance can also be a beneficial property, such as when it
23 assists in warding off to some extent loss in hardness arising out of heating
24 of the core during welding of the projections to the core or during frictional
25 engagement with rock when the tooth is in use.

26 One example of suitable metals for the core is carbon steel conforming to
27 ASTM Standard A-27, preferably grade 70-36. Because of their low cost
28 and ease of welding, these are considered best for applications in which
29 the core will not be subjected to heavy abrasion, such as where only softer
30 rock is to be fractured and or the projections extend far beyond the fronts of
31 the cores. Where greater abrasion resistance is needed, it is considered
32 best to use cast steels conforming to AISI 8630 or ASTM A148, preferably
33 grade 90-60, either of which type of material has been quenched and

1 tempered to any suitable hardness level, for example a BHN of about 300
2 to about 400. Other suitable core metals include, for example, the
3 remnants of worn, cast rock fracturing teeth, such as those manufactured
4 by Hensley and others.

5 Approximate compositions of a number of these core metals, by weight, the
6 balance being iron, appear below:

	<u>Metal</u>	<u>C</u>	<u>Mn</u>	<u>P</u>	<u>S</u>	<u>Si</u>	<u>Cr</u>	<u>Ni</u>	<u>Mo</u>	<u>Cu</u>	<u>V</u>	<u>Al</u>
8	90-60	.32	1.5	.05	.05	.45			.4			
9	8630	.3	.8	.03	.03	.23	.5	.55	.2			
10	Hensley	.28	.64	.02	.01	1.2	1.7	.2	.4	.04	.02	.03
11	Other	.31	1	.02	.01	1.2	2	.05	.45	.02	.01	.01

12 The specific examples of metals set forth above appear sufficient in fracture
13 resistance and temper resistance and the other properties enumerated
14 herein for purposes of making cores. However, it is believed that there is a
15 wide variety of other suitable metals and that persons skilled in the
16 metallurgical arts are able to adjust metals composition and heat treatments
17 applied to such other metals to achieve desired levels of weldability and
18 durability to produce acceptable cores. For further guidance on effecting
19 desired levels of hardness, fracture resistance, temper resistance and other
20 beneficial properties, see U.S. Patents 5,525,167 and 5,595,614 and other
21 patents identified therein, the disclosures of all such patents being
22 incorporated herein by reference in their entireties.

23 Cores may be formed as one or more castings (single casting preferred) or
24 as a fabricated assembly of segments of plate or non-plate components or
25 in any other suitable way from any suitable new (virgin or used metal not
26 previously employed as a tooth core) or used (previously used as a portion
27 of a tooth) material. Examples of used materials include the remaining
28 shanks of tooth from which the projections have been worn away. Used

1 cores are not preferred, due to expectation of undependable supply.
2 However, used cores, where available, can be made into teeth better than
3 the originals.

4 Preferred embodiments of cores have front ends that include front surfaces
5 of any workable shape, rear ends with any shape consistent with the
6 connector function, described below and a longitudinal axis. The
7 longitudinal surface(s) of the core may have a surface or surfaces of any
8 number or shape, including one (e.g., cylindrical) and plural (e.g., three or
9 more) (four preferred). As viewed in transverse cross-section, the core's
10 exterior surface may be of any shape, symmetric or asymmetric, for
11 example, may be at least partly circular, oval, triangular, square,
12 rectangular, diamond, polygonal, parallelogram, trapezoidal, modifications
13 of any of the foregoing, composite shapes (combinations of the above), e.g.
14 generally square but with rounded corners. Such cross-section may be
15 uniform or variable along its length, but is preferably flattened on two sides
16 where two projections are welded to it. The longitudinal cross-section of
17 the core's exterior surface may have any suitable shape, may be uniform or
18 variable along its length, may be tapered, at least in part (preferred), may
19 have divergent "land(s)" on which to weld divergent projection(s), when
20 divergent projections are used and may be non-tapered.

21 Teeth fabricated according to the invention have one or more projection(s)
22 which may for example be fabricated from metallic stock, such as bar stock,
23 but preferably from plate stock. The metallic stock has a composition
24 and/or treatment history contributing to the presence, in the stock, of
25 properties of wear resistance, fracture resistance and temper resistance
26 sufficient for satisfactory fabrication of and service in excavating teeth.

27 Preferably the metallic stock is abrasion resistant steel, having a
28 composition and treatment history being sufficient to provide in the stock a
29 surface BHN (Brinell Hardness Number) of at least about 225. Still more
30 preferably, the metallic stock is an abrasion resistant quenched and
31 tempered steel alloy which comprises iron, carbon, manganese and silicon,
32 and optionally but preferably at least one additional alloying element
33 selected from the group consisting of chromium, nickel, boron,

1 molybdenum, vanadium, titanium, copper, aluminum, niobium and nitrogen,
2 the amounts of the aforementioned constituents and the treatment history
3 of the stock being sufficient to provide in the stock a surface BHN of at least
4 about 300, more preferably at least about 350, still more preferably at least
5 about 375 and most preferably at least about 400. Most preferably, the
6 sulfur and phosphorous contents of the stock are respectively less than
7 about 0.05, preferably less than about 0.04 and still more preferably less
8 than about 0.030 percent by weight of the entire metallic stock.

9 Preferably, the wear resistance, fracture resistance and temper resistance
10 of the projection metallic stock and resultant projections are sufficient for
11 the projections to remain useful for fracturing rock, while avoiding major
12 breakage of the projections and retaining at least about 50, at least about
13 70 or at least about 85% of their as-manufactured hardness, in rock
14 excavating service, over a period of at least about 4, more preferably at
15 least about 8, and still more preferably at least about 16 and most
16 preferably at least about 40, hours of operation. In some instances, where
17 a particular projection of very hard metal tends to be quite brittle, a
18 workable tooth may be manufactured by using metallic stock having less
19 hardness.

20 Suitable metals are available, including for example USS (United States
21 Steel) AR 225, AR 350, AR 400 and AR 500, USS T-1 and USS T-1, types
22 A, B and C, and USS Ni-Cr-Mo; Lukens Hardwear (tm) 235, 400, 425 and
23 500; Bethlehem AR 235, RQC, RQAR, RQA, RQB and RQ; Astralloy-V;
24 and Oliver Formable 400 and Ultra-Tuff plate. Particularly preferred are
25 plates identified as Hardox 400 and especially Hardox 500, respectively
26 having the following reported properties:

1		Hardox 400	Hardox 500
2		(about)	(about)
3	BHN hardness	360-440	450-560
4	yield strength	145 ksi	190 ksi
5	tensile strength	180 ksi	225 ksi
6	elongation (A5)	10%	8%
7	impact properties		
8	(Charpy V, longitudinal specimen)	18 ft. lbs. (at -40F)	18 ft. lbs. (at +14F)

10 Materials of higher hardness levels may be used.

11 The above illustrative metals are believed sufficient in fracture resistance,
 12 temper resistance and other properties enumerated above to be useful in
 13 making projections for use in the present invention. However, it is believed
 14 that a wide variety of other suitable metals is available and that persons
 15 skilled in metallurgy can adjust metals composition and heat treatments
 16 applied to such other metals to achieve desired levels of weldability and
 17 durability to produce acceptable projections. For further guidance on
 18 effecting desired levels of hardness, fracture resistance, temper resistance
 19 and other beneficial properties in projections, see U.S. Patents 5,525,167
 20 and 5,595,614 and other patents identified therein, the disclosures of all
 21 such patents being incorporated herein by reference in their entireties.

22 Projections of any acceptable thickness can be employed, for example
 23 about 1/2 to about 3 inches, frequently about 3/4 to about 2 and 1/4 inches,
 24 and in many instances about 1 to about 1 and 1/2 inches, most preferably
 25 about 1 and 1/4 inches for the applications with which the most experience
 26 has been acquired.

27 As the tips of projections are brought to bear on rock, sufficient force must
 28 be applied in order to penetrate the rock. Otherwise, the tips will only rub
 29 across the surface and no fracturing or "digging" will occur. More powerful
 30 equipment is able to supply more force per unit of tip area, which of course,

1 all other things remaining equal, is a function of thickness. Thus, in teeth
2 for use on more powerful equipment, thicker metallic stock may be used in
3 making the projections, and longer wear would be expected from thicker
4 projections. However, the tips of narrower projections made from thinner
5 metallic stock would be expected to enable a given piece of equipment to
6 exert more force per unit area on the rock strata, and thus penetrate the
7 strata more easily. Accordingly, it is beneficial to select projection
8 thickness with the goal of effecting a balance between service life and ease
9 of penetration. For applications in which ripping arms bearing one or two
10 teeth comprising a total of two to four projections made from plate stock are
11 employed on a large power shovel, such as a Caterpillar 385, a plate
12 thickness of about 1.25 inches is presently considered optimum. It should
13 be noted that it can be necessary or desirable to adjust characteristics
14 other than projection thickness when preparing teeth for more and less
15 powerful excavating machines.

16 Monolithic projections are preferred. A monolithic projection is composed
17 substantially of a single thickness of a given portion of metallic stock.

18 The projections have "major surfaces". In the case of projections formed
19 from plate stock, the major surfaces are those portions of the projections
20 that, if not surface-modified after cutting from the plate, were originally part
21 of the largest surfaces of the plate stock, i.e., the top and bottom surfaces
22 as distinguished from the edges; and it is for this reason that they are
23 referred to as "major" surfaces. In the projections, these major surfaces are
24 usually and preferably, but not necessarily, of larger area than any of the
25 other surfaces, i.e., than the peripheral edges, of the projections. In the
26 case of projections cut from bar stock that has approximately planar
27 surfaces on opposite sides thereof that are approximately parallel, and
28 preferably also in the case of projections cut from plate, the major surfaces
29 are preferably those that are approximately parallel to the digging direction
30 of the tooth. Approximately planar, as applied to bar stock, means at least
31 nearly flat (i.e. essentially flat or, if its surface is arcuate, having a radius of
32 at least 10, preferably at least 15 and more preferably at least 20 times its
33 width) throughout at least 80, preferably at least 90 and more preferably at
34 least 95 percent of its width. Approximately parallel, as applied to opposed

1 surfaces of a bar, means nearly parallel, i.e., with an angle of up to 20,
2 more preferably less than 10, still more preferably less than 5 and most
3 preferably zero degrees between those surfaces. Approximately parallel,
4 as applied to the relationship between a digging direction and a surface of a
5 projection, means that surface is more nearly parallel than perpendicular to
6 that direction, more preferably at an angle to one another that is up to
7 about 35 degrees, more preferably up to about 25 degrees, still more
8 preferably up to about 15 degrees and most preferably about 9 degrees or
9 less, including zero degrees.

10 Preferably, in the finished tooth, the abrasion resistance of each projection
11 intermediate its major surfaces is at least a major fraction of its abrasion
12 resistance at its major surfaces; preferably, the hardness of the projections
13 intermediate their major surfaces is at least about 60, about 70, about 80,
14 or above 90, percent of its major surface hardness.

15 One or more cut edges are present on projections cut from plate. Two or
16 more edges may be cut from plate stock. However, one or more edges
17 may correspond to the edge of a plate and thus will not be cut from the
18 plate. Plate stock is preferably cut by an automatically guided gas jet
19 cutter. For many of the available types of plates, their manufacturers
20 recommend pre-heating prior to cutting and give specific recommendations
21 as to temperature limits. These should be considered.

22 Projection edges may be of straight, curved, saw-tooth, stepped or other
23 configuration(s), and the corners of the projections may be rounded,
24 chamfered, or not. Preferably, there will be at least two edges having
25 portions that converge to a tip. Convergence may be along straight, curved
26 or other forms of axes to provide dagger shape, "hook" shape or any other
27 suitable shape. Moreover, the convergence may be symmetrical or non-
28 symmetrical, of uniform or non-uniform slope relative to the axis/axes and
29 continuous or non-continuous. Where a projection is formed from bar
30 stock, e.g. square bar stock, all of the convergence may be in portions of
31 the edges closely adjacent the tip. Ranges of exemplary included angles of
32 convergence between edges, e.g., throughout their length or only as the
33 edges approach the tip, include about 10 to about 35 degrees, preferably

1 about 15 to about 30 degrees, more preferably about 17 to about 25
2 degrees, and still more preferably about 21 ± 2 degrees. It is currently
3 considered optimum/best for fracturing hard rock under heavy force to have
4 the edges converge at about $21\frac{1}{4}\pm 1$ degrees. One or both of the
5 convergent edges may be chamfered, but these are preferably not
6 chamfered.

7 As to the nature of the tip, it may be a sharp point if desired, but this is not
8 necessary. While the tip may be squared off, a rounded tip is preferred.
9 The tip may be cut as a segment of a circle with a radius of, e.g., about 0.1
10 to about 1 inch, preferably about 0.2 to about 0.7 inch, more preferably
11 about 0.2 to about 0.4 inch and most preferably about 0.3 inch.

12 For an excavating machine capable of exerting a given force, larger and
13 smaller tip radii respectively, all other factors remaining equal, result in the
14 application of less and more fracturing force per unit area to rock strata.
15 Thus, in selecting tip radii when designing teeth according to the invention,
16 persons skilled in the art may wish to consider short radii for less powerful
17 equipment and vice versa. While having a proper tip radius can be
18 important when a tooth is first placed in service, it should be understood
19 that such radius is likely to change or wear to a different shape as the tooth
20 wears.

21
22 The shape of other edges and corners of the projections may be varied
23 widely as desired, e.g., may be straight, curved and/or of other suitable
24 shapes.

25 Tooth length may also vary widely as appropriate for digging and for
26 providing enough overlap of projection and core to allow formation of welds
27 of the requisite strength between them.

28 While the number of projections may be at least one per tooth, preferably
29 two projections per tooth are preferred. There may be more than two
30 projections per tooth. Where there are plural projections, it is preferred that
31 there be divergence of one or more of these projections, for example
32 divergence of the outer surface of a projection from a central axis of the

1 tooth or divergence of the outer surface of a projection from the outer
2 surface of another projection.

3 When divergence is present, for example, in at least one projection of a
4 tooth employed in trenching, moderate divergence assists the operator,
5 when desired, in keeping the side of the trench vertical and in squaring off
6 an intersection between a side and the bottom of the trench. Where
7 vertical side walls and squared-off side-wall to bottom-wall intersections are
8 not required or may be achieved in another way, at least one, e.g., all, of
9 plural projection(s) in a tooth may be mounted with one or both of its/their
10 major face(s) parallel to or convergent with the tooth axis. Where there is
11 divergence, it may for example be about 1 to about 15, preferably about 6
12 to about 12, more preferably about 8 to about 10 and most preferably about
13 9, degrees from the tooth axis. Where the angle of divergence is
14 expressed as the angle between major surfaces of two projections, the
15 above maxima and minima of the above ranges are doubled. There can be
16 an advantage in limiting the amount of divergence to no more than is
17 needed to facilitate "squaring off"; in some tooth designs, careful control
18 over the divergence angle will contribute to the strength of the tooth.

19 Providing divergence of one or more projections from the core axis, when
20 such is provided, can be facilitated by securing a projection to a core side
21 which, overall, is generally divergent from the core axis at the projection
22 angle of divergence. Alternatively, one may secure a projection to a "land"
23 representing a portion of the side of a core, the land being angled from the
24 core central axis at the projection angle of divergence. Where a projection
25 is not secured in the above manner, e.g., where the core has parallel sides,
26 one or more shims may be placed between the inner surface of the
27 projection and the adjacent surface of the core to orient the projection at
28 the desired angle during fabrication, e.g., during welding.

29 In securing projections to cores, portions of projections may be secured in
30 slots or grooves formed in cores or to longitudinal surface(s) of cores,
31 which is preferred, or in any other way. A pair of projections is preferably
32 secured to opposite sides of a core. However, one may also secure a first
33 projection in a central groove at the front end of core, and secure second

1 and third projections to opposite sides of core. When at least one
2 projection is secured to at least one longitudinal surface of the core, which
3 is preferred, such projection(s) may and preferably do extend along at least
4 a portion of the at least one longitudinal surface and a portion of said at
5 least one projection extends past the front end of the core with the tip and
6 at least a portion of the converging edges projecting beyond the front end
7 of the core.

8 Although other securing methods may be employed, welding is preferred.
9 One may employ any suitable welding techniques, which may include
10 cleaning, e.g., by wire wheel or other means, and preheating the core
11 and/or projection for any suitable time and temperature by any suitable
12 heating method under any suitable atmosphere, e.g., to 150-200 degrees
13 F. in air with a gas torch. One may employ any suitable welding process,
14 flux, atmosphere, wire/rod type, temperature during welding, and any other
15 details that might be considered useful. SMAW and GMAW are examples
16 of suitable welding methods. In general, for welding excavator tooth
17 projections to cores, it is considered good practice to form welds between
18 the parts everywhere possible. Among the post-welding operations/steps
19 to be considered are cool-down processing (time, temperature,
20 atmosphere), quenching, wrapping the hot welded part in a welding blanket
21 to inhibit cracking of welds. Plate manufacturers' recommendations should
22 be considered.

23 A preferred welding procedure which has provided good results includes
24 cleaning the surfaces to be welded by wire wheel, locating the projection(s)
25 properly located on the core and tack welding them in place. The location
26 of the plates is then checked. Now, 3/32" diameter T75 flux-core wire is
27 applied to the joint where projection meets core. A preferred cover gas of
28 100% C0₂ is used with the T-75 wire. It is best to apply multiple passes in
29 filling the joint. In addition, the temperature of the work-piece is held at 600
30 degrees F. or less. After the welding operation, the finished part is
31 immediately wrapped in an insulating blanket for several hours to allow for
32 slow cooling to ambient temperature, thus avoiding formation of cracks in
33 the weld areas and heat-affected zone of the weld.

1 Teeth according to the invention comprise part of a connector, called the
2 tooth connector portion, which is adapted to cooperate with another part of
3 a connector, called the excavator connector portion, located on an
4 excavator apparatus, as further described below. In this way, the tooth and
5 excavator apparatus may be connected to one another in working
6 relationship. The tooth connector portion is located in or on the core,
7 preferably at (in, on or near) the rear end of the core and more preferably in
8 or on the rearmost surface of the core. However, the tooth connector
9 portion may be located in or on other surfaces of the core, e.g., its top
10 surface, where such exists, its bottom surface, where such exists, a lateral
11 surface(s), where such exists, or the front surface, where such exists.

12 The tooth connector portion includes at least one concave or convex
13 connector surface, which may have circular configuration, may have any
14 other suitable configuration and may be tapered or not tapered, but tapered
15 surfaces are preferred for most applications. Viewed in transverse cross-
16 section, the connector surface may for example appear at least partly
17 circular, oval, triangular, square, rectangular, diamond-shaped, polygonal,
18 of parallelogram shape, trapezoidal, a modification of any of the foregoing
19 or a composite shape (combinations of any of the above, e.g. generally
20 square but with rounded corners). The transverse cross-section may
21 appear uniform or variable along most if not all of its length.

22 In longitudinal cross-section, the connector surface may be of any suitable
23 shape, whether uniform or variable along its length, including not tapered or
24 tapered, the latter being preferred.
25

26 The connector surface of the tooth connector portion is positioned and
27 adapted to engage with and non-destructively disengage from at least one
28 mating surface of an excavator apparatus.

29 Locking members may be provided to secure teeth to excavator apparatus.
30 For examples of different locking members, both metallic, partly metallic
31 and non-metallic, see U.S. Patents 6,047,487; 5,937,550; 5,638,621;
32 5,617,655; 5,579,594; 4,891,893; 5,653,048; 5,526,593; 6,079,132 and
33 6,247,255, which are incorporated herein by reference. It is not necessary

1 however that teeth according to the invention be held in fixed relation to
2 their adapters; for reciprocation of projections or teeth by air or hydraulic
3 drives, see U.S. Patent 5,495, 685.

4 For purposes of the present invention, an excavator apparatus is any
5 excavating machine adapted to carry, in working position, one or more
6 teeth constructed according to the invention, such as a mechanical or
7 hydraulic power shovel, backhoe, trackhoe, dragline or shaft drill. In
8 addition to such machines, excavator apparatus includes any digging
9 attachment or combination of attachments adapted to be mounted on an
10 excavating machine and to carry, in working position, one or more teeth
11 constructed according to the invention, such as a blade, bucket, ripper arm,
12 cutting chain, dredge cutterhead, quick-tool-connect/disconnect attachment
13 or any suitable form of tooth adapter used with any of the foregoing.

14 Excavator apparatus usually comprises, as included or attached elements,
15 one or more excavator connector portions that have one or more concave
16 or convex surfaces adapted to mate with and form, in cooperation with one
17 or more tooth connector portions of the core, at least a portion of a robust
18 connector for securing a tooth or teeth to the excavator apparatus with
19 sufficient strength to resist the loads imposed thereon in rock excavating
20 service. The mating surface(s) on the excavator connector portions and on
21 the tooth connector portions with which they cooperate preferably represent
22 a nearly exact match, so that one fits snugly within the other in order to
23 minimize relative movement of the surfaces after it/they is/are securely
24 seated against or within one another. However, these surfaces need not in
25 all circumstances be an exact match for one another or be in interfacial
26 contact over their entire confronting areas. They need only abut one
27 another over sufficient area to provide the required strength and load
28 resistance.

29 In preferred applications of the invention, a major surface of at least one
30 projection is maintained approximately perpendicular to an axis of an
31 excavator apparatus. Approximately perpendicular means more nearly
32 perpendicular to than parallel to an axis, which may for example be the axis
33 of a pin or pivot, or an axis around which an identified part such as a ripper

1 arm pivots, or may be an edge of a part such as a bucket or blade. If one
2 or more projections have their major surfaces angled vertically and/or
3 horizontally (e.g., tilted and/or splayed) with respect to a plane that is
4 perpendicular to such an axis, such angle(s) will be selected to limit
5 resultant tearing forces on welds and/or other connections between the
6 projections and their mountings (e.g., cores) as necessary to provide
7 commercially acceptable resistance to breakage of those connections and
8 of the projections themselves during operation, and more preferably to
9 essentially prevent such breakage. Preferably, such angle(s) will be in the
10 range of up to about 35 degrees, yet more preferably up to about 25
11 degrees, and most preferably up to about 15 degrees, including zero
12 degrees. About 9 degrees is considered best. If the major surfaces are not
13 planar, e.g., are of curved, corrugated or other cross-section, the angle of
14 those surfaces relative to the axis may be judged on the basis of a sound
15 approximation, for example, in the case of corrugation, the angle could
16 possibly be measured in reference to a plane which includes the peaks of
17 the corrugations; or in the case of a curved cross-section, the angle could
18 possibly be measured in reference to a plane which includes the edges of
19 the curved cross-section.

20 Benefits can be realized from preferred embodiments of the invention
21 involving particular orientation of teeth relative to digging direction in
22 excavator apparatus. In these embodiments, the teeth comprise one or
23 more projections having a major surface/surfaces having a selected
24 orientation relative one or more planes that is/are transverse to the
25 excavator digging axis (e.g., the axis of rotation of an excavator arm
26 relative to the excavator boom). Preferably, one or more projections is/are
27 respectively in planes that are approximately perpendicular to the arm-
28 boom axis. Still more preferably, each tooth comprises at least two
29 projections that are in planes which diverge from one another at
30 progressively greater distances in the direction of their tips. Preferably
31 tooth connector portion and mating portion of the excavator apparatus are
32 sufficiently symmetrical to permit rotation of the tooth and projections 180
33 degrees, so that direction of digging by the projections can be reversed and
34 the wear on the projections can be equalized.

1 DETAILED DESCRIPTION OF DRAWINGS

2 Figures 1-2

3 Figures 1 and 2 illustrate a particularly preferred embodiment of an
4 excavator tooth according to the present invention, having a metallic core
5 with first and second projections 3 and 4. Were this core of circular
6 transverse cross-section, which is an optional embodiment of the invention,
7 the core could have a single, cylindrical, longitudinal surface. However, in
8 the present figures, the core has four longitudinal surfaces, including top 5,
9 bottom 6, first side 7 and opposite side 8. Its ends include front end 9 and
10 rear end 10.

11 A connector portion 13 is located at rear end 10 of the core and more
12 preferably in the rearmost surface of the core. Connector portion 13
13 includes a concave connector surface 14, which may be of circular or other
14 configuration, positioned and adapted to engage with and non-destructively
15 disengage from at least one mating surface (not shown) of an excavator
16 apparatus (not shown).

17 In the present disclosure and claims, wherever reference is made to a
18 concave or convex connector surface, whether in or on a core, or in or on
19 an excavator apparatus, the singular form of the word "surface" includes
20 the plural of this term. For example, connector surface 14, corresponding
21 in shape with a truncated pyramid, comprises five surfaces, including those
22 of four convergent inner walls 15 and of end wall 16.

23 Core rear end 10 also includes rearwardly projecting ears 17 with apertures
24 18 in them to receive a locking pin (not shown). These assist in fixing the
25 excavator tooth to any form of excavator apparatus, such as an adaptor
26 (not shown).

27 First projection 3 includes inner and outer major surfaces 20 and 21 while
28 second projection 4 includes inner and outer major surfaces 22 and 23. In
29 this preferred embodiment, inner major surfaces 20 and 22 have an angle
30 of divergence 24 between them.

1 Convergent cut edges 25 and 26 of each of these major surfaces, which
2 terminate in tip 27, define between them an angle of convergence 28. The
3 projection back edges 29 blend into edges 25 and 26 through short arcs 30.

4 Welds 31 join the back edges 29 and portions 33 of the projections to
5 portions 32 of the core. Portions 34 of the projections, not welded to the
6 core, face one another and extend forward away from the core.

7 Exemplary dimensions for the embodiment just described, which has been
8 found suitable for rock excavating service on power shovels, include an
9 overall length, from the backs of the ears 17 to the tips 27 of projections 3
10 and 4 measuring 16 inches, a total projection length from back edges 29 to
11 tips 27 of 9 inches, a convergence of projection cut edges 25 and 26 of
12 21.25 degrees, a radius for tips 27 of 0.3 inches, a radius of 0.5 inches for
13 arcs 30, a maximum vertical spread of the projection cut edges 25 and 26,
14 near their back edges 29 of 3.67 inches, a separation of the projection
15 outer major surfaces 21 and 23 from one another, at their tips 27, of 10.75
16 inches, an angle of divergence of 18 degrees between the inner major
17 surfaces 20 and 22 of the projections and a projection thickness of 1.25
18 inches where the projections have been cut from commercially available
19 Hardox 500 plate stock.

20 Figure 3

21 This figure illustrates an excavator to 38 having a metallic core 39 of used
22 material, in this case a used cast tooth from which the remnants of the worn
23 digging points have been ground away. There are also first and second
24 projections 40 and 41, similar to those of the preceding embodiment.

25 Core 39 comprises four longitudinal surfaces, including a top surface 42, a
26 bottom surface (not shown), a first side 43 and an opposite side (not
27 shown). This core also has front end 44 and rear end 45. Rear end 45
28 comprises tooth connector portion 48 including a concave connector
29 surface at 46, similar to that of the preceding embodiment, as well as ears
30 50 and locking pin apertures 51.

1 Figure 4

2 In this embodiment, excavator tooth 55 has a first projection 56, in the
3 foreground of the view, and a second projection 57 in the background.
4 While the inner major surface of first projection 56 is not shown, its outer
5 major surface 58 is in the foreground of the view. A portion of the inner
6 major surface 59 of the second projection may be seen where a portion of
7 the first projection has been broken out in the view. The outer major
8 surface of the second projection is at the back of the part and thus it is not
9 shown in this view.

10 The inner major surfaces of the projections may be parallel, convergent or
11 preferably divergent, as viewed from above. Each projection has a lower
12 convergent edge 60, upper convergent edge 61, tip 62 and back edge 63.

13 Unlike the previous embodiments, the core and tooth connector portions of
14 the present embodiment are fabricated rather than cast. They include an
15 upper inclined plate 67 and lower inclined plate 68 which are welded to and
16 extend laterally between the inner major surfaces of projections 56 and 57.

17 Plates 67 and 68 are removed by a substantial distance 69 from projection
18 tips 62. These two plates comprise convergent inner surfaces 70 and 71,
19 representing a concave or female connector surface, e.g., pocket 72.
20 Apertures 73, positioned in plates 67 and 68 intermediate the projection
21 inner surfaces, are provided for insertion of a locking pin, as discussed
22 below.

23 In this figure, an excavator apparatus is represented by a portion of an
24 adaptor 74. It may for example be located on a digging implement or on
25 any earth-working portion of an excavating machine. Here adaptor 74
26 includes a body 75 comprising a convex mating surface compatible with
27 pocket 72. Body 75 also includes a bore 77 which is in registry with
28 apertures 73 when the tooth is installed on excavator apparatus 74 and
29 held in place with the aid of locking pin 78.

1 Figures 5-6

2 While former embodiments disclose fixing projections to outer surfaces of
3 cores, one can construct useful excavator teeth in which one or more
4 projections are mounted within one or more portions of a core. Figures 5
5 and 6 illustrate this.

6 This embodiment includes forked core 82 comprising main body 83 with
7 forwardly projecting first and second arms 84 and 85, defining between
8 them a cavity 86. Here, a single projection 87 having cut edges 88, tip 89
9 and back edge 90, the latter being defined by two angled portions 91 and
10 92, is secured in cavity 86. Such securing is accomplished by welds 93
11 between the back 94 of the cavity and the angled portions 91 and 92 of
12 projection back edge.

13 Here, the tooth connector portion is, for example, a male member 99,
14 preferably of truncated pyramidal shape. It extends rearwardly from the
15 end 100 of core main body 83. The mating surface is a female member, for
16 example a cavity 101 in an excavator apparatus 102, shown in phantom
17 outline in figure 6.

18 A locking member, for example bolt 103, passes through matching holes
19 104 and 105 in tooth connector portion 99 and excavator apparatus 102.
20 By engaging the tooth and a portion of the excavator apparatus, this bolt
21 provides security for the connection between the tooth connector portion
22 and its mating surface in the excavator apparatus.

23 Figures 7-9

24 Excavator teeth according to the invention can be used in virtually any kind
25 of digging implement, for example above ripping arms illustrated in figures
26 7-9. In figure 7, an excavator tooth 107 having projections 108 is affixed to
27 a ripping arm 106 with the aid of locking pin 109.

28 As shown in figure 8, a ripping arm, such as arm 106 of figure 7, may be
29 secured to a base plate 110. Webs 111 projecting from the rear of base

1 plate 110 may be equipped with mounting pins 112 to engage with a quick-
2 connect-disconnect appliance, by means of which this digging implement
3 may be installed on an excavating machine, such as a power shovel or
4 backhoe.

5 Figure 9 includes a base plate 110, webs 111 and mounting pins 112,
6 similar to those of figure 8. However, here, two ripping arms 106 are
7 secured to the base plate.

8 In figures 8 and 9, mounting pins 112 have axes 113. Major surfaces 114
9 of the projections 108 are approximately perpendicular to these axes.

10 Figure 10

11 This figure illustrates another type of digging implement on which excavator
12 teeth of the present invention may be used. Here, the digging implement is
13 a dredge cutter-head 117. It comprises central rotary shaft 118 having an
14 axis of rotation 119 which is perpendicular to the plane in which this view is
15 drawn. Spiral vanes 120, extending from shaft 118 have inner ends 121
16 and outer ends 122, support ring 123 being secured to the latter. A plurality
17 of adapters 124 may be installed on ring 123 for mounting excavator teeth
18 125 with projections 126 whose major surfaces 127 are approximately
19 perpendicular to axis 119.

20 Figures 11-12

21 Yet another type of digging implement in which the present invention is
22 useful is excavator buckets. As will be shown, such buckets may have
23 rectilinear or non-rectilinear cutting edges.

24 Bucket 131 of figure 11 includes sides 132, a back 133 and a bottom 134,
25 having a substantially rectilinear cutting edge 135. Edge 135 defines a
26 digging axis 136. Along this edge is distributed a series of adapters 137 on
27 which excavator teeth 138 according to the invention is mounted. Major
28 surfaces 139 of protrusions 140 in these teeth have their major surfaces
29 positioned approximately perpendicular to digging axis 136.

1 The bucket 143 in figure 12 comprises sides 144, a back 145 and a bottom
2 146, having across its front an at least partly non-rectilinear cutting edge
3 147. Reference line 149, drawn through points at which the ends 148 of
4 edge 147 intersect with sides 144, represents the digging axis of the
5 bucket. Adapters 150, distributed across cutting edge 147, are provided for
6 mounting a series of excavator teeth 151 on the bucket. To reduce clutter
7 in the drawing, the teeth have been omitted from two of the five adapters.
8 Each excavator tooth includes projections 152 having major surfaces 153
9 that are approximately perpendicular to digging axis 149.

10 Figure 13

11 Teeth fabricated according to the present invention can be utilized in a wide
12 variety of excavating machines, one example of which is the rubber-tired
13 backhoe machine illustrated schematically in figure 13. It includes body
14 157, and, at the front of the machine, a bucket 158, bucket arms 159 and
15 bucket pivot 160. Rotational axis 161 of this bucket is perpendicular to the
16 plane in which the figure is drawn and therefore is represented by a dot at
17 the center of the pivot. A series of excavator teeth 162, only one being
18 shown in this view, is distributed across the front edge of the bucket, for
19 example in a manner similar to that shown in figure 11 or 12. These teeth
20 have projections 163 with major surfaces 164 approximately perpendicular
21 to axis 161.

22 Towards the rear of the machine is a boom 168 having a base pivot 169
23 upon which the boom may be raised and lowered. Upper pivot 170, having
24 pivot axis 177, is a pivot point for excavator arm 171, which is mounted at
25 the upper end of the boom. At the lower end of the arm is an end pivot 172
26 on which a digging implement, for example pivoting rock ripping implement
27 173, is mounted. Hydraulic boom lift cylinder 174, arm pivoting cylinder
28 175 and implement pivoting cylinder 176 are provided to raise and lower
29 the boom, and move the arm and ripping implement back and forth.
30 Excavator teeth according to the invention can also be used with backhoe
31 units equipped with means to allow the boom to swivel from side to side
32 around a vertical axis, but that feature has been omitted from the present
33 drawings to simplify them.

1 At the center of end pivot 172 is a pivoting axis 181 about which ripping
2 implement 173 pivots when digging through rocky strata. Excavator teeth
3 178, made according to the present invention, have projections 179. Their
4 major surfaces 180 are approximately perpendicular to axes 177 and 181.

5 Figure 14

6 Excavator teeth according to the invention have demonstrated their
7 durability in service on the buckets of large power shovels, such as that
8 shown schematically in figure 14. Typical machines of this type move on
9 crawler tracks 185 and include a body 186, boom 187, boom base pivot
10 188, boom lift cylinder 189, arm 190, boom-arm pivot 191, arm pivoting
11 cylinder 192, implement 193, in this case a rock ripping arm, implement
12 pivot 194 and implement pivoting cylinder 195. Pivots 188, 191 and 194
13 include, respectively, pivoting axis 200 about which the boom swings up
14 and down, pivoting axis 201 about which the arm swings in and out and
15 pivoting axis 202 about which the implement swings back and forth.

16 Implement 193 is equipped with excavator teeth 203 according to the
17 invention. They include projections 204, the major surfaces 205 of which
18 are approximately perpendicular to axes 200, 201 and 202.

19 Figures 15-16

20 Another example of many types of excavating machines on which the
21 excavator teeth of the present invention may be used is draglines, an
22 example of which is shown schematically in figures 15-16. As is usual in
23 such equipment, this embodiment includes main boom 210 having base
24 pivot 211, overhead cable system 212 to support -- and winch cable system
25 213 to draw -- bucket 214, all as shown in figure 15.

26 Base pivot 211 has a pivoting axis 215. As shown in greater detail in figure
27 16, bucket 214 has excavator teeth according to the present invention with
28 projections 217. These projections have major surfaces at least some and
29 preferably all of which that are approximately perpendicular to axis 215.

1 The present disclosure has discussed and illustrated a number, but
2 certainly not all, of the different ways in which the present invention may be
3 practiced. Accordingly, the following claims are intended to cover all the
4 embodiments falling within their literal scope, whether specifically disclosed
5 herein or not, and all equivalents thereof.

6 **DEFINITIONS**

7 Excavate, excavating, excavation, excavator, digging, ripping and related
8 terms employed herein are intended to be construed broadly to include all
9 forms of earth moving whether they result in formation of a cavity in the
10 earth or not. For example, these terms include not only trenching, dredging
11 and formation of other types of open cavities in the earth or in the earthen,
12 including rocky, sub-soil of a body of water, but also ripping, scraping,
13 stripping, grading, leveling and other forms of earth moving that disturb
14 earth, as distinguished from merely carrying it from one place to another.
15 In this context, earth includes not only soil, but also frozen soil, gravel and
16 layers at or below the earth's surface comprising mostly mineral matter and
17 which may be essentially all rock, and may include solid rock strata, which
18 represents a particularly useful application of the invention.

19 What is claimed is: